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(54) Foamable drilling fluid

(57) A foamable drilling fluid for use in well operations such as deep water offshore drilling where risers are not employed in returning the fluid to the surface mud pit comprises a prehydrated clay such as bentonite: water: a surfactant selected from α-olefinsulfonates. alkylpolyglycosides. alcohol sulfates and salts of ethoxylated alcohol sulfates. and a stabilizing surfactant such as cocoamine betaine. The drilling fluid can also contain an hydraulic material selected from Portland cement. siliceous material like fumed silica, blast furnace slag and pozzolans such as fly ash.

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Description

The present invention relates generally to a drilling fluid and, more particularly, to a foamable drilling fluid for use in well operations such as deep water offshore drilling.

A variety of fluids are known for use in drilling wellbores. Conventionally, a wellbore is drilled using a drilling fluid that is circulated through the wellbore. After the wellbore is drilled, the circulation of the drilling fluid is stopped, the well is logged and a string of pipe is run in the wellbore. After the pipe is run, the drilling fluid in the wellbore is cleaned up by circulating drilling fluid downwardly through the interior of the pipe and upwardly through the annulus between the exterior of the pipe and the walls of the wellbore while removing drilling solids and gas therefrom. Primary cementing operations are then performed in the wellbore, i.e. the string of pipe disposed in the wellbore is cemented therein by placing a cementing composition in the annulus between the pipe and the walls of the wellbore.

Single phase (liquid only) water based drilling fluids are commonly used in both onshore and offshore operations whereas two phase (liquid and gas), often referred to as foamed drilling fluids, are typically used only in onshore drilling operations. Conventional offshore drilling fluids consist of sea water as the base fluid and are circulated from the well annulus to the sea floor.

Offshore well completions at depths in excess of 2000 feet of water are often referred to as "deep water" operations. In certain deep water operations, such as in the Gulf of Mexico, the formations where conductor pipe is cemented that is less than 2000 feet below mud line (BML) are generally young geologically and are not well consolidated. The formations generally are the product of erosion from the continental shelf. This can cause numerous problems in cementing the casing in the wellbore.

Some standard offshore drilling operations for drilling the conductor casing intervals do not utilize a riser for returning the drilling fluid to the surface mud pit wherefore acceptable drilling fluids must be environmentally safe for return to the sea floor. As a result, most offshore drilling fluids consist essentially of sea water.

Numerous offshore drilling problems result from not having a riser to return drilling fluids to the mud pit and from using primarily sea water as the drilling fluid. Importantly, the use of sea water alone provides little or no fluid loss control, and the use of fluid loss additives therewith is uneconomical because risers are not used and the drilling fluid is lost when circulated to the sea floor. Fluid loss from a sea water based drilling fluid allows the cuttings and particulates circulated during drilling to form the basis of a thick mud filter cake build up in the annulus, which compromises the long term integrity of the cement job because filter cake buildup against the formation face provides a pathway for undesired water or sand flow

Hence, numerous advantages are gained when a stable two phase (liquid and gas) foamed drilling fluid is used in offshore drilling operations. The stable foamed drilling fluid, which consists of system analogous to an emulsion with gas as the internal phase and liquid as the external phase, has low fluid loss which results in less filter cake buildup in the annulus of the well and a better cement job. The foaming action imparts greater volume to the starting fluid volume. Larger fluid volumes improve cuttings removal because the concentration of cuttings in the mud often reaches a saturation point in these drilling operations At the saturation point, the only way to remove additional cuttings from the well is to increase the fluid volume pumped. The viscosity of the foamed drilling fluid allows effective lifting of relatively large particles having a diameter of several inches. This characteristic of a foamed fluid is particularly important in a large annulus where any fluid encounters reduced velocity and thereby reduced cuttings carry-capacity. Density of the foamed fluid is easily adjusted through control of the amount of gas used in foaming the fluid thereby increasing the operational ease of handling. Decreased leak-off from the foamed fluid results in less clay swelling thus reducing the chances of having washed out portions in the wellbore. Also, the foamed fluid has a lower hydrostatic pressure which reduces the chance of fracturing the formation when low fracture gradients are present in the wellbore.

Known foam drilling fluids are used in conjunction with risers or the like for returning the fluid to the rig floor. Hence, the foam fluids are unstable and break down when the drilling action ceases or the fluids are returned such that the cuttings are easily separated from the returns and the fluid can be recirculated into the well. Additionally, the unstable foamed fluid will release suspended cuttings and allow them to return downhole if the drilling action ceases while the fluid is in the wellbore.

There is a need for a stable foamed fluid that does not break down and return cuttings downhole if the drilling action ceases, which is especially desirable in wellbores having a large annulus. To date, no stable foamed fluids have been used in operations having risers because the volume of the returns would be unmanageable without foam breakdown. Hence, in well operations without risers, it is desirable to provide a stabilized foam drilling fluid which is environmentally safe since returns are circulated to the sea floor.

Furthermore, it is desirable to have a foamed drilling fluid which includes hydraulic materials to setup the filter cake and by-passed mud thereby preventing many of the problems presented herein. The hydraulic material solidifies the filter cake, reduces the filter cake permeability, and provides better bonding with conventional cement slurries. Nevertheless, until now, no foamed drilling fluid containing an hydraulic material has been provided.

We have now devised a stable and environmentally safe foamable drilling fluid by which many of the above re-

quirements can be met

According to the present invention, there is provided a foamable drilling fluid composition for use in drilling operations, which composition comprises a starting fluid comprising prehydrated clay; water; a foaming surfactant for use in foaming the drilling fluid, and a stabilizing surfactant for stabilizing the drilling fluid after the fluid is foamed.

The invention also includes a method of using a foamable drilling fluid composition in deep water offshore drilling operations, which comprises the steps of drilling a wellbore, foaming a drilling fluid composition of the invention and circulating the foamed drilling fluid in said wellbore

Wellbores are commonly drilled using a rotary bit connected to a string of drill pipe. The drill pipe and bit are rotated and a drilling fluid is circulated downwardly through the drill pipe, through ports in the drill bit and then upwardly through the annulus between the drill pipe and the walls of the wellbore to the surface. The drilling fluid transports cuttings produced by the drill bit to the surface. The present invention provides a stable and environmentally safe foamed drilling fluid for use in offshore drilling operations where the foamed fluid is circulated to the sea floor. As such, a preferred foamable drilling fluid comprises a starting fluid made from a clay such as bentonite, attapulgite or sepiolite and is prehydrated with fresh water, sea water, or common salt solutions. Further, the preferred foamable drilling fluid includes sea water, a foaming surfactant for foaming the fluid and a stabilizing surfactant for stabilizing the foamed fluid. The foaming surfactant is selected from the group consisting of α-olefinsulfonates, alkylpolyglycosides, alcohol sulfates or salts of ethoxylated alcohol sulfates. A sufficient amount of stabilizing surfactant, such as cocoamine betaine, is used in the fluid for reducing foam breakdown upon drilling cessation, reducing filter cake buildup and increasing the carrying capacity of cuttings and other solids.

In addition, a foamable drilling fluid is provided which includes an hydraulic material selected from the group consisting of Portland cement siliceous material like fumed silica, blast furnace slag and pozzolans such as fly ash The hydraulic material solidifies the filter cake and any by-passed mud, reduces the filter cake permeability, and provides better bonding with conventional cement slurries.

As mentioned above, the foam drilling fluid composition and methods of the present invention are for use in well drilling operations, and particularly in deep water offshore drilling where a riser is not being utilized. The present invention provides a stable and environmentally safe foamable drilling fluid composition and methods of use therefor. Additionally, the present invention provides a foamable drilling fluid including an hydraulic material.

A preferred starting fluid comprises a clay such as bentonite, attapulgite or sepiolite which is prehydrated in fresh water, sea water, or salt solution to form a slurry. Water, preferably sea water, brine or other common salt solution, is added to the starting fluid in the range from about 0 bbl to about 2 bbl per bbl of starting fluid slurry. A foaming surfactant for use in foaming the drilling fluid is selected from the group consisting of α-olefinsulfonates, alkylpolyglycosides, alcohol sulfates, and salts of ethoxylated alcohol sulfates. Preferred foaming surfactants are commercially available under the tradenames "AQF-2" and "CFA-S" from Halliburton Energy Services of Duncan, Oklahoma. Other available foaming surfactants include "FDP-C485", "HOWCO SUDS", and "SIMULSOL-10"; wherein the "FOP-C485" and "HOWCO SUDS" surfactants are available from Halliburton Energy Services of Duncan, Oklahoma; and the "SIMULSOL-10" surfactant is available from Seppic, Inc., of Fairfield, New Jersey. The foaming surfactant concentration is provided in the range from about 1% to about 4% by volume of water (BVOW).

The preferred stabilizing surfactant consists of cocoamine betaine and is available under the tradename "HC-2" from Halliburton Energy Services of Duncan, Oklahoma. The stabilizing surfactant concentration is provided in the range from about 0.5% to about 2% BVOW. A sufficient amount of stabilizing surfactant is used for stabilizing the foamed drilling fluid (i.e. the foamed drilling fluid will not significantly breakdown in the wellbore upon drilling cessation).

Barite may be added to the drilling fluid composition as a weighting material for achieving a desired drilling fluid density. In addition, an hydraulic material may be added to the composition wherein the hydraulic material is selected from a group consisting of Portland cement, siliceous material like fumed silica, blast furnace slag and pozzolans such as fly ash. The barite and/or hydraulic material are added in the drilling fluid in an amount necessary for achieving a desired density of the unfoamed drilling fluid composition. The density of the unfoamed drilling fluid composition can range from about 9 to about 17 lbs/gal, while the density of the foamed drilling fluid composition is in the range from about 6 to about 13 lbs/gal. The preferred density of the unfoamed drilling fluid is in the range of about 13 lb/gal to about 15 lb/gal, while the preferred foamed drilling fluid density is about 9 lb/gal to about 12 lb/gal.

Various preferred ranges for the drilling fluid composition are set out below.

Preferred Ranges for Different Materials			
	(% BVOW)	Amount (% Barite/Hydraulic Material)*	Starting Density (lb/gal)
Class F Fly Ash			
Surfactants			
"HOWCO SUDS"/"HC-2"®	2/1	75/25	15
"AQF-"2/"HC-2"	4/2	85/15	15
Class C Fly Ash			
Surfactants			
"AQF-2"/"HC-2"	2/1	0/100	13
Silicalite (Compacted Powder or Liquid)			
Surfactants:			
"AQF-2"/"HC-2"	4/2	50/50	13
SLAG.			
Surfactants:			
"SIMULSOL"®-10/"HC-2"	4/2	0/100	15
"AQF-2"/"HC-2"	1/0.5	0/100	15

* Percent in an amount necessary for achieving a desired density of the unfoamed drilling fluid composition in the range from about 9 to about 17 lbs/gal

Other fluid loss control additives, such as carboxymethylcellulose, starch, co-polymer of NNDMA & AMPS, poly anionic cellulose, and/or dispersants such as sulfonated styrene maleic anhydride and lignin based materials, can be utilized in the drilling fluid.

The drilling fluid composition provided herein is pre-mixed using conventional rig equipment such as mud mixing pits, and is preferably foamed using a tee foam generator. The tee foam generator is comprised of a choke nozzle (part no. 439.00272), ceramic insert (part no. 643.0355) and T-body (425.80463), each of which is available from Halliburton Energy Services of Duncan, Oklahoma. The tee foam generator introduces nitrogen, compressed air or other suitable gas into the drilling fluid composition.

The methods of using the foamable drilling fluid composition in deep water offshore drilling operations basically comprise the steps of drilling a wellbore; providing a foamable drilling fluid as described herein; foaming the drilling fluid; and circulating the foamed drilling fluid composition in the wellbore. The foamed fluid may be used in periodic sweeps of the wellbore as staged with conventional drilling fluids. Further, the circulating foamed drilling fluid may include the hydraulic material which either with activation or time will solidify the filter cake.

To further illustrate the present invention, and not by way of limitation, the following examples are provided.

EXAMPLE I

Dynamic fluid loss tests were performed using sweeps of the foamed drilling fluid composition of the present invention at a test temperature of 60°F and a pressure of 120 psi. The recipes of the compositions tested and the test results are set out in TABLE I, below.

Each of the compositions included prehydrated bentonite (at a concentration of 30 lb/bbl bentonite in fresh water), sea water and barite, while some of the compositions included either blast furnace slag, fumed silica or fly ash (Class C). Various amounts of foaming surfactant, stabilizing surfactant and additional fluid loss additives were employed in the testing. The data indicates the grams of filtrate which were collected over time using a "METTLER" Balance.

Referring now to TABLE I, it is seen that optimum filtrate ranges are provided using various concentrations of hydraulic materials and surfactants.

TABLE I

Dynamic Fluid Loss Tests
(Test Temperature 60°F - Pressure 120 psi)

TEST NO.	I[*]	II[*]	III[*]	IV[*]	V[*]	VI[*]
Sea Water (bbl)	1	1	0.5	0.5	0.5	0.5
Barite %[a]	100	100	100	85	85	85
Other Material %[a]	0	0	0	Slag 15	C Fly Ash 15	Silicalite 15
Unfoamed Density (lb/gal)	15	10.5	15	15	15	15
Foamer % BVOW						
"CFA-S"	4	--	--	--	--	--
"AQF-2"	--	0	4	4	2	4
HC-2 Stabilizer % BVOW	2	0	2	2	2	2
Other fluid loss additive						
"PAC-L" (ppb)[b]	1	1	--	1	0.75	1
"X-TEND" II (ppb)[b]	--	0.2	--	--	--	--
"HALAD®-4" (ppb)	--	--	--	--	1.5	--

[*] Prehydrated Bentonite (bbl) - 30 lb bentonite in 1 bbl fresh water

[a] Percent of barite and other hydraulic material is added in an amount necessary for achieving a desired density of the unfoamed drilling fluid composition in the range from about 9 to about 17 lbs/gal

[b] "PAC-L" and "X-TEND II" additives were obtained from Baroid Drilling Fluids, Houston, Texas

TABLE I (Continued)
Fluid Loss Rate at grams per minute

TEST NO. Time (Minute)	I	II	III*	IV	V	VI**
0.5	28.8	---	23	5.6	---	---
1	23	5.29	7.2	4.2	9.1	14.1
2	3.6	0.99	3.9	---	1.8	1.6
5	2.57	0.73	2.7	1.75	0.98	2.43
10	1.62	0.52	1.8	2.41	0.88	1.1
15	1.14	---	1.4	---	0.62	0.86
20	1.08	0.38	1.3	---	0.48	0.86
30	1.06	0.3	1.25	0.74	0.37	0.71
40	0.54	0.3	0.93	0.58	0.33	0.55
50	0.63	0.23	0.86	0.51	0.32	0.58
60	0.56	0.26	0.75	0.53	0.54	0.49
70	0.54	0.26	0.7	0.48	0.3	0.35
80	0.53	0.18	0.68	0.47	0.23	0.31
90	0.5	0.2	0.62	0.39	0.18	0.31

* Sea water was reduced to 0.5 bbl from 1 bbl
** 50% active liquid Silicalite

EXAMPLE II

Foam stability and rheology tests were performed at room temperature, unless indicated otherwise, using various foam drilling fluid compositions containing hydraulic materials including either fly ash (Class C), blast furnace slag, compacted silicate or fly ash (Class F). The recipes of the compositions tested and the test results are set out in TABLES II, III, IV and V, below.

TABLE II

Class C Fly Ash

Sample No.	Prehydrated Bentonite bbl	Sea Water bbl	Barite* %	Class C Fly Ash* %	Initial Density ppg	"AQF-2" % BVOW	"HC-2" % BVOW	Foamed Density ppg	Foam Stability
1	1	1	0	100	13	4	2	---	too thick to foam
2	1	1	50	50	13	4	2	9.7	thinner, stable
3	1	1	85	15	13	4	2	10.1	stable
4	1	2	15	85	13	1	0.5	9.7	viscous, stable
5	1	2	0	100	13	2	1	9.7	stable

* Percent of barite and other hydraulic material is added in an amount necessary for achieving a 13 lb/gal density of unfoamed drilling fluid.

Rheology
(rpms - dial reading from a rotary viscometer)

Sample No.	600	300	200	100	6	3
1	---	---	---	---	---	---
2	112	92	81	66	28	25
3	80	62	50	35	12	11
4	186	141	128	117	59	56
5	110	94	88	79	34	31

TABLE III

SLAG

Sample No.	Prehydrated Bentonite bbl	Sea Water bbl	Barite* %	Slag* %	Initial Density ppg	"AQF-2" % BVOW	"HC-2" % BVOW	Foamed Density ppg	Foamed Stability
1	1	1	0	100	15	4	2	10.5	too thick to foam
2	1	1	0	100	13	4	2	9.8	stable
3	1	1	15	85	15	4	2	10.4	stable
4	1	1	50	50	15	4	2	10.4	stable
5	1	1	85	15	15	4	2	9.9	stable
6•	1	0.5	85	15	15	4	2	9.7	stable

* Percent of barite and other hydraulic material is added in an amount necessary for achieving a 13 lb/gal density of unfoamed drilling fluid

• 1.0 "PAC-L" additive was added (grams/1600 cc volume)

Rheology
(rpms - dial readings from a rotary viscometer)

Sample No.	600	300	200	100	6	3
1	175	161	148	123	48	35
2	82	70	67	63	32	23
3	93	74	68	62	48	35
4	78	56	41	34	27	25
5	60	38	30	24	21	19
6	113	74	62	49	33	32

TABLE IV

(Fumed Silica)

Sample No.	Prehydrated Bentonite bbl	Sea Water bbl	Barite* %	Fumed Silica* %	Initial Density ppg	"AQF-2" % BVOW	"HC-2" % BVOW	Foamed Density ppg	Foamed Stability
1	1	1	15	85	13	4	2	--	too thick* to foam
2	1	1	50	50	13	4	2	10	stable*
3	1	0.5	85	15	15	4	2	10.5	stable
4	1	1.5	75	25	15	2	1	9.8	stable
5	1	0.5	85	15(active)**	15	4	2	10	stable

* 15g "Supercizer 7"
** Liquid Suspension of fumed silica (50% active)
* Percent of barite and other hydraulic material is added in an amount necessary for achieving a 13 lb/gal density of the unfoamed drilling fluid

Rheology
(rpms -- dial readings from a rotary viscometer)

Sample No.	600	300	200	100	6	3
1	---	---	--	--	--	--
2	126	81	67	50	22	19
3[1]	190	126	102	71	30	29
4[2]	144	96	78	57	31	30
5[3]	138	86	69	47	16	15

[1] 0.75g "PAC-L", 1.5g "HALAD-344" added (grams/1600cc volume)
[2] 0.5g "PAC-L", 1g "SSMA" added (grams/1600cc volume)
[3] 1g "PAC-L" (grams/1600cc volume)

TABLE V

Class F Fly Ash

Sample No.	Prehydrated Bentonite bbl	Sea Water bbl	Barite* %	Class F Fly Ash* %	Initial Density ppg	"AQF-2" % BVOW	"HC-2" % BVOW	Foamed Density ppg	Foamed Stability
1	1	1	85	15	15	2	1	10	not stable
2	1	1	85	15	15	4	2	10.5	stable
3	1	1	75	25	15	(Howco Suds) 2	1	9.6	stable

* Percent of barite and other hydraulic material is added in an amount necessary for achieving a 13 lb/gal density of the unfoamed drilling fluid

Rheology
(rpms - dial readings from a rotary viscometer)

Sample No.	600	300	200	100	6	3	Other Additives grams/1600cc volume
1	300+	187	137	79	10	7	4g "LAP-1"[1], 0.7g "SSMA"[2]
2	192	139	105	70	53	45	1g "PAC-L"
3	225	147	116	78	21	19	4g "LAP-1", 1g "LP-55"

[1] "LAP-1" is an additive obtained from Halliburton Energy Services, Duncan, Oklahoma

[2] "SSMA" is sulfonated styrene maleic anhydride available from Alco, a division of National Starch and Chemical Company in Bridgewater, New Jersey

Referring now to TABLES II-V, it is seen that foam stabilities are provided using various hydraulic materials.

The present invention of utilising foamed drilling fluid has a number of benefits, such as increasing the drilling fluid viscosity for cleaning the wellbore and carrying solids, imparting fluid loss control to the drilling fluid, adding volume to the original fluid, imparting gel strength to stabilise the wellbore and minimise washed out regions, and allowing easy adjustment of the drilling fluid density.

Claims

1. A foamable drilling fluid composition for use in drilling operations, which composition comprises a starting fluid comprising prehydrated clay; water; a foaming surfactant for use in foaming the drilling fluid; and a stabilising surfactant for stabilising the drilling fluid after the fluid is foamed.

2. A composition according to claim 1, wherein the water is fresh water, sea water or brine.

3. A composition according to claim 1 or 2, wherein the foaming surfactant is an α-olefinsulfonate, alkylpolyglycoside, alcohol sulfate or salt of an ethoxylated alcohol sulfate.

4. A composition according to claim 1, 2 or 3, wherein the foaming surfactant is present in the drilling fluid in an amount of from 1% to 4% by volume of the water.

5. A composition according to claim 1, 2, 3 or 4, wherein the stabilizing surfactant comprises cocoamine betaine.

6. A composition according to any of claims 1 to 5, wherein the stabilizing surfactant is present in the drilling fluid in an amount of from 0.5% to 2% by volume of the water.

7. A composition according to any of claims 1 to 6, further comprising an hydraulic material.

8. A composition according to claim 7, wherein the hydraulic material is Portland cement, siliceous material, blast furnace slag or a pozzolan

9. A composition according to claim 7 or 8, further comprising barite.

10. A composition according to claim 7, 8 or 9, wherein the hydraulic material and any barite are present in the drilling fluid in an amount necessary to provide the drilling fluid composition with an unfoamed density in the range of 9 to 17 lbs/gal.

11. A method of using a foamable drilling fluid composition in deep water offshore drilling operations, which comprises the steps of drilling a wellbore; foaming a drilling fluid composition as claimed in any of claims 1 to 10; and circulating the foamed drilling fluid in said wellbore.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 6495

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-5 213 161 (B.J.KING) * column 2, line 14 - column 3, line 28 * * column 3, line 52 - column 4, line 21 * ---	1-6,11	C09K7/08 C09K7/02 B01F17/00
Y,P	EP-A-0 695 795 (COMPAGNIE DES SERVICES DOWELL SCHLUMBERGER) * page 2, line 57 - page 3, line 13 * * page 3, line 26 - line 30; examples 1-4 * ---	1,11	
Y	FR-A-2 439 230 (SEPPIC) * page 1, line 24 - line 29 * * page 3, line 1 - line 28 * * claims 1-9; examples 1-3 * ---	1,2,5,11	
Y	US-A-4 201 678 (D.S.PYE) * column 3, line 39 - column 5, line 10 * * column 5, line 47 - column 6, line 10; examples 1-13 * ---	1-3,5,11	
Y	FR-A-2 690 709 (SEPPIC) * page 3, line 15 - line 31 * * page 6, line 9 - line 24; example 1 * ---	1-3,5,11	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)** C09K B01F
Y	EP-A-0 070 076 (THE PROCTER & GAMBLE COMP.) * page 1, line 6 - line 11 * * page 1, line 25 - page 3, line 6 * * page 5, line 17 - line 23 * * page 6, line 1 - line 9 * * page 9, line 18 - page 10, line 23 * * page 12, line 30 - page 13, line 4 * -----	1-3,5,11	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 November 1996	Boulon, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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